High Perceptual Load Makes Monocular Attention Different

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Attention is a fundamental function of the human which is important in our daily life. Perceptual load is thought to play an important role in selective attention[1,2]. When perceptual load is high, the distracting information will be kept out of perception and will not affect us. When perceptual load is low, the distracting information will be processed deeply by us and will influence us[3]. However, most of the past research was concerned with binocular attention instead of monocular attention. In spite of the differences such as visual acuity[4], stereopsis[5,6] between binocular and monocular vision, there were few reports of their difference regarding to perceptual load which means more items and features in our research. Here we show their difference with the application of perceptual load to a selective attention task adapted from Eriksen's flanker task[7]. According to our research, monocular subjects are more sensitive to perceptual load with a lower perceptual load keeping them from the distracting effect. The difference may be attributed to less perceptual capacity rather than better attention of monocular vision. The research revealed a difference between binocular and monocular perceptual capacity and provides a new perspective to study the neural mechanism of perceptual capacity.

Experiment 1

In experiment 1 the subjects' performance under load 2 was examined. The results suggest that binocular and monocular performances are different.

Binocular attention is distracted by the distractor with incompatible reaction time significantly longer than compatible. However, it's not the case with monocular attention.

Repeated Measures analysis was performed after experiment 1 on the subjects' reaction times and accuracy with eye (binocular versus monocular view), compatibility (compatible versus incompatible distractor) as within-subjects variables.

The significant effect of distractor compatibility [$F(1, 39) = 15.172$, $p<0.001$] indicated that generally it took more time for the subjects to complete tasks with incompatible distractor than compatible and our distractor application was successful.

Of particular interest, a significant interaction between eye and compatibility was found [$F(1, 39) = 6.161$, $p=0.017$], indicating there is different compatibility effect between binocular and monocular attention.

No significant effect was found in accuracy analysis.

Of further interest, we performed t-test analysis under either view condition separately and found that the compatibility effect was significant under binocular condition [$t(39) = -4.238$, $p<0.001$] while insignificant under monocular condition [$t(39) = -0.756$, $p=0.454$].

According to the past research, perceptual load is related with compatibility effect. When perceptual load is high, the compatibility effect will fade away. Thus, performances under one lower and two higher perceptual loads besides load 2 were examined in Experiment 2.

Experiment 2

In Experiment 2, the subjects' performances under load 1, 2, 4 and 6 were examined.

Repeated Measures analysis was performed after experiment 2 with reaction times and accuracy as dependent variables and eye (binocular view and monocular view), compatibility (compatible and incompatible), load (perceptual load 1, 2, 4, 6) as within-subjects factors.

There were significant effects of compatibility [$F_{(1, 23)} = 16.552$, $P<0.001$] and load [$F_{(3, 69)} = 125.463$, $P<0.001$), indicating our successful application of distractor and perceptual load respectively.

Particularly, an interaction between eye and compatibility [$F_{(1, 23)} = 6.437$, $P=0.018$] confirmed the different compatibility effect between binocular and monocular attention. No other effect with eye as a factor was found.

Accuracy analysis showed a significant effect with load [$F_{(3, 69)} = 28.116$, $P<0.001$] and an interaction between compatibility and load [$F_{(3, 69)} = 3.669$, $P=0.016$], indicating lower accuracy and less compatibility effect with load increases. No other effect with eye as a factor was found, suggesting the interaction between eye and compatibility in reaction time analysis could not result from time-accuracy trade-off.

We also performed paired-samples t test between incompatible and compatible reaction times of binocular and monocular view separately to examine the compatibility effect under each load. Significant compatibility effect of binocular view under load 1, 2 and 4 was observed as the past research[8,9,10]. Of particular interest, a significant compatibility effect was observed only under load 1 of monocular view [t (23) =5.025, p<0.001], which implicates that the insignificant monocular compatibility effect observed in experiment 1 can not be simply attributed to better distractor inhibition. Lavie's perceptual load theory suggest that high perceptual load will take up the perceptual capacity without spare capacity for the distractor and there will not be distracting effect. According to the theory, what we observed implicates that monocular perceptual capacity is consumed faster than binocular condition.

Although the compatibility effects of binocular and monocular attention are both affected by perceptual load, they are not affected to the same degree. Monocular attention, compared to binocular attention, is more sensitive to perceptual load. This difference is observed in our research and was not reported in the past research. This observation may help us better study attention and perceptual capacity, especially the neural mechanism underlying perceptual capacity.

Methods

Subjects

Subjects were recruited from the students of the University of Science and Technology of China. None of the subjects reported a history of neurological problem. Experiment 1 included 20 students (4 women and 16 men; mean age = 21.5 years old). Experiment 2 included 24 students (7 women and 17 men; mean age = 20.0 years old).All the subjects are myopic in both eyes and have corrected-to-normal vision of either eye as tested by the standard logarithmic visual acuity chart test.

Stimuli

Stimuli were presented on a 17-in. SONY CPD-G220 monitor from a standard PC equipped with a NVIDIA GeForce 9800 GT video card using OpenGL routines. Subjects were seated with their eyes 57 cm from the monitor in a darkened room. Each stimuli included three kinds of items (target, non-target, and distractor) presented in white on a black background.

Target letters and non-target letters held an average of 0.9° vertically and 0.85° horizontally as illustrated in Figure 1. They were presented at the locations arranged around the central fixation point at a distance of 2.3°. The distance between the center of adjacent letters was also 2.3°. The positions on which target and non-target letters appeared were randomly selected across trials. Central distractor held 0.4° vertically and 0.4° horizontally. The central distractor was always inside the ring, 0.5° from the center either to the left or to the right. The target letters consisted of ‘X’ and ‘N,’ non-target letters consisted of the letters ‘Z,’ ‘M,’ ‘W,’ ‘H,’ and ‘K,’ and distractor letters consisted of ‘X’ and ‘N’.

Procedure

We examined the subjects to ensure which eye was the dominant eye at first. After that we corrected the subjects’ dominant eye to a level of normal visual acuity tested by the standard logarithmic visual acuity chart and then the slave eye to the same level. The subjects’ visual acuity was counterbalanced between binocular and monocular condition by decreasing a same degree of the myopic lens of either eye to ensure the tasks under the two conditions were fulfilled with the same visual acuity level. The subjects used the dominant eyes with their fellow eyes patched under monocular condition.

Each trial began with a 500-msec fixation point followed by a 100-msec presentation of the stimuli. Participants were instructed to determine whether ‘X’ or ‘N’ had appeared in one of the six peripheral positions as soon as possible while ensuring accuracy and trying to neglect the central distractor. Participants should press the key ‘0’ and ‘2’ of a standard keyboard’s numerical pad to indicate ‘X’ and ‘N’ , respectively. They should always use their right index fingers to press the key ‘0’ and middle fingers the key ‘2’. The view order of the subjects was counterbalanced as well as target position, distractor position, identity and their combinations.

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Figure 1. Different stimuli of perceptual loads used in the research. The higher perceptual load has more items and features. Subjects were instructed to determine whether ‘X’ or ‘N’ had appeared in one of the six peripheral positions as soon as possible while ensuring accuracy and trying to neglect the central distractor. The reaction time of the subjects was recorded. The view order is counterbalanced as well as target position, distractor position, compatibility of target and distractor. The distracting effect is calculated by subtracting compatible reaction times from incompatible reaction times.

Fig 2. Mean reaction times of Binocular and monocular view under load 2. Compatible and incompatible conditions are shown separately. Just as presented in the figure, binocular reaction time is different under compatible and incompatible condition compared to monocular. Statistically, binocular reaction time is significantly shorter under compatible condition than incompatible while monocular reaction time shows no significant difference between either condition.

Fig 3. Mean reaction times of binocular **(a)** and monocular **(b)** attention under load 1, 2, 4 and 6. Compatible and incompatible conditions are shown separately. As presented in the figure, binocular distracting effect is significant under load 1, 2, 4 while monocular distracting effect is only significant under load 1.

Table 1. Reaction Times (Milliseconds) and Compatibility Effect (Mean ± Standard Error) under load 2.

	Load 2
Binocular view	
Incompatible	608.1±15.5 (4.2)
Compatible	585.2±14.8 (2.8)
Compatibility effect	22.9±5.4 (1.4)**
Monocular view	
Incompatible	610.8±15.4 (2.8)
Compatible	607.1±16.5 (2.6)
Compatibility effect	3.7±4.9 (0.2)

** $p<0.01$

Table 2. Reaction times (Milliseconds) and Compatibility Effect (Mean ± Standard Error) under 4 different loads.

	Load 1	Load 2	Load 4	Load 6
Binocular view				
Incompatible	506.2±20.6(2.8)	575.0±21.8(4.8)	711.3±27.9(7.4)	774.8±35.7(8.7)
Compatible	485.8±19.0(3.4)	553.5±19.9(3.5)	677.2±28.1(5.4)	758.9±34.9(8.7)
Compatibility effect	20.4±7.7(-0.6)*	21.5±9.9(1.3)*	34.2±12.9(2.0)*	15.9±14.3(0.0)
Monocular view				
Incompatible	485.3±12.6(3.0)	554.1±14.1(3.6)	710.6±24.8(7.2)	785.7±29.9(7.6)
Compatible	462.5±11.4(2.0)	552.5±14.8(3.5)	700.6±21.6(4.3)	797.3±29.2(10.7)
Compatibility effect	22.8±4.5(1.0)	1.6±6.9(0.1)	10.0±11.0(2.9)	-11.5±16.2(-3.1)

* $p<0.05$

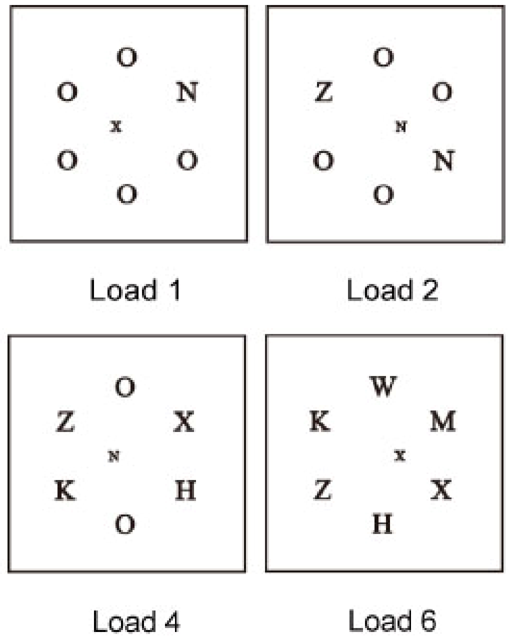

Fig 1

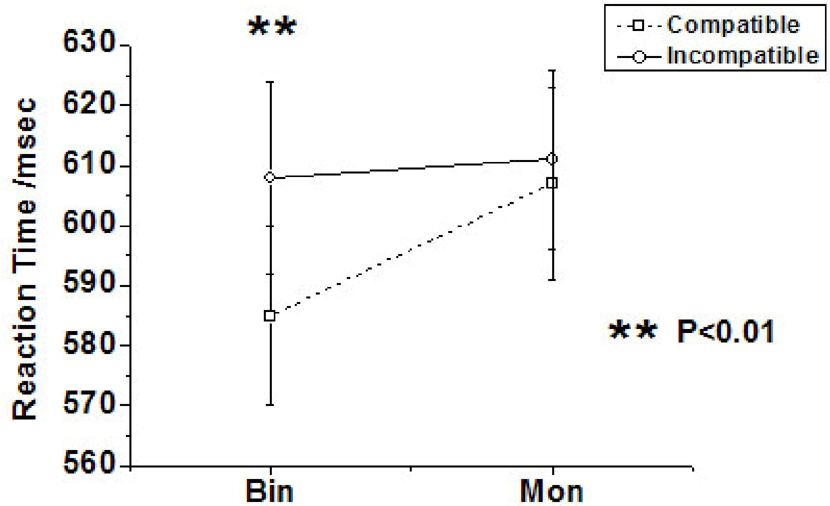
**
630
620
610
600
590
580
570
560
Reaction Time /msec
Bin
Mon
Compatible
Incompatible
** P<0.01

Fig 2

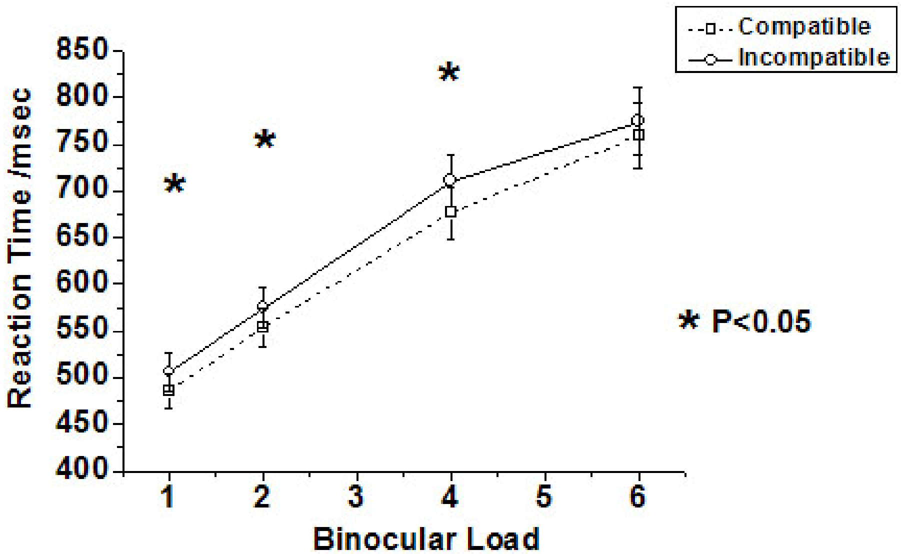
Compatible
Incompatible
850
800
750
700
650
600
550
500
450
400
Reaction Time /msec
1
2
3
4
5
6
Binocular Load
*
*
*
* P<0.05

Fig 3a

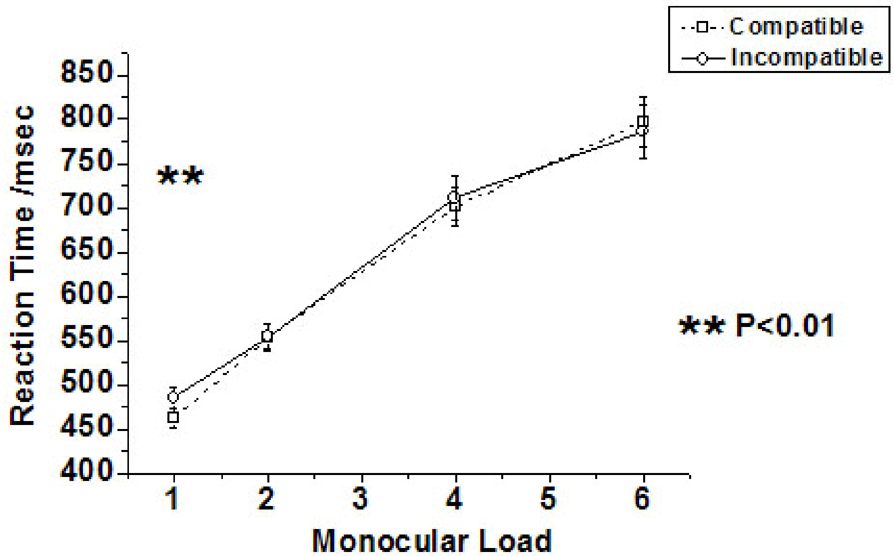
Compatible
Incompatible
Reaction Time /msec
850
800
750
700
650
600
550
500
450
400
**
1
2
3
4
5
6
Monocular Load
** P<0.01

Fig 3b